Antiferromagnetic Spin Reorientation at the Co/NiO(001) Interface Observed by XPEEM

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BACKGROUND

The exchange bias phenomenon plays a key role in magnetic-device technology, such as the giant magnetoresistance (GMR)-effect read heads. But exactly how exchange bias works is not very well understood. The spin orientation on each side of the antiferromagnet/ferromagnet interface is one of the missing pieces of information. We addressed this issue by studying nickel oxide single crystal exhibiting a (100) oriented surface. Nickel oxide single crystals have been well characterized in the literature and exhibit large antiferromagnetic domains which X-ray Photoemission Electron Microscopy (XPEEM) with a spatial resolution of 50 nm for magnetic structures can easily image using the technique of x-ray magnetic linear dichroism (XMLD). Image contrast arises because the relative orientation of the polarization of the x-ray beam and the magnetic axis in the antiferromagnetic domains influences the shape of the x-ray absorption spectra. To image ferromagnetic cobalt layers, we used x-ray magnetic circular dichroism (XMCD) with circularly polarized light. By employing the surface sensitivity of XPEEM we can then compare our data to the well known bulk data.

RESULTS

The first set of XMLD measurements, made on bare nickel oxide, revealed a complex domain pattern related to that previously known for bulk single crystals, but with some differences. In the bulk, the domains are defined by the (111) crystallographic planes in which the spins lie and the [211] directions in which they are aligned. Analysis of the XPEEM images yielded the same [211] magnetic axes but in a different arrangement. In addition, the XPEEM data showed that some of the boundaries between the domains (domain walls) had decreased magnetic symmetry (Figure 1).

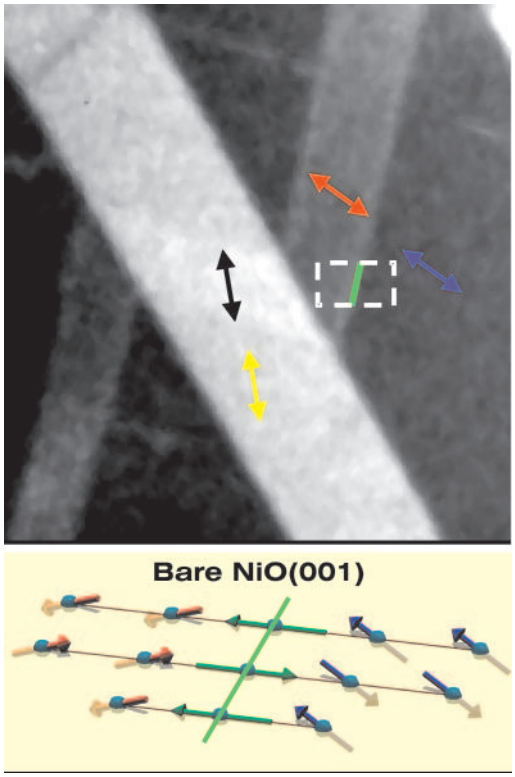

Figure 1: Antiferromagnetic domains on NiO(001)in an area 12 μm across. The colored arrows indicate the projections of the antiferromagnetic axes in the surface plane for four types of domains. Domains with identical in-plane projections (e.g., those marked with red and blue arrows) can be distinguished by examining their orientation out of the surface plane, as illustrated in the sketch at the bottom for the area in the dashed box. The green line represents a domain wall where the spins are in-plane

In a second step we deposited 8 monolayer of ferromagnetic cobalt layer by electron beam evaporation. Upon deposition a reorientation of the nickel spins takes place such that only domains with walls in (100) crystallographic planes remained (Figure 2). Moreover, the spins in the domains assumed [110] directions parallel to the interface. XMCD measurements showed that the magnetization in the cobalt domains was aligned, domain by domain, parallel to the magnetic axes of the nickel oxide domains. Heating the sample to above the Néel temperature destroys the correlation, indicating that the domain pattern observed is indeed caused by exchange coupling between the two systems.

We conclude that a realistic model of exchange bias cannot rely on the bulk structure of the antiferromagnet but has to consider deviations of the spin axis at the interface. These experiments are made possible by the unique combination of chemical, magnetic and surface sensitivity of XPEEM in combination with a tuneable and polarized x-ray source.

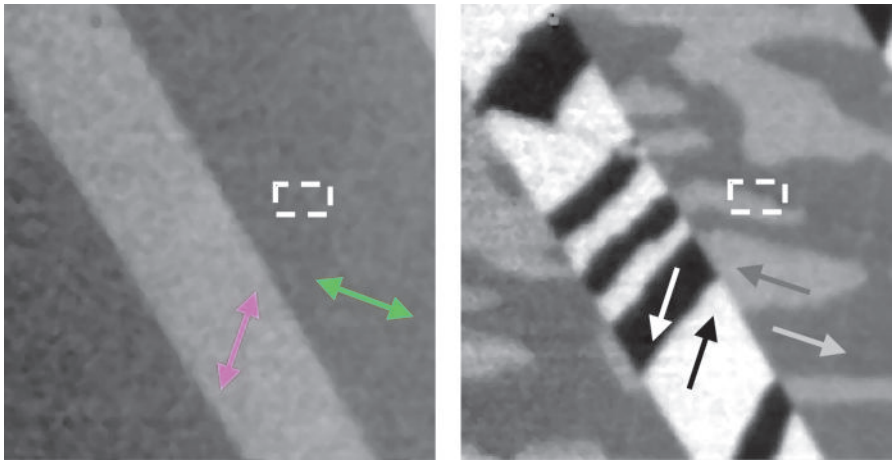

Figure 2: Antiferromagnetic (left) and ferromagnetic (right) domains after deposition of eight monolayers of cobalt. The antiferromagnetic axes have rotated into the surface plane so that only two types of domains can now be distinguished. On top of each antiferromagnetic domain, two ferromagnetic domains can be formed with their magnetization in either of two directions parallel to the antiferromagnetic axis underneath.

References

[1] H. Ohldag, A. Scholl, F. Nolting, S. Anders, F.U. Hillebrecht, and J. Sthr, *"Spin reorientation at the antiferromagnetic NiO(001) surface in response to an adjacent ferromagnet*, Phys. Rev. Lett. **86**, 2878 (2001).

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